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NATIONAL BUREAU OF STANDARDS REPORT

2972

A STUDY OF THE CEMENT TESTING PROGRAM
OF THE NATIONAL BUREAU OF STANDARDS

By

W. S. Connor and W. H. Clatworthy

U. S. DEPARTMENT OF COMMERCE
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A STUDY OF THE CEMENT TESTING PROGRAM
OF THE NATIONAL BUREAU OF STANDARDS

By

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Statistical Engineering Laboratory

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

FOREWORD

This report illustrates a statistical approach of wide applicability, and was prepared in the Statistical Engineering Laboratory of the National Bureau of Standards, for the information and use of the Bureau's Mineral Products Division.

Churchill Eisenhart
Chief, Statistical
Engineering Laboratory

A. V. Astin
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A STUDY OF THE CEMENT TESTING PROGRAM OF THE NATIONAL BUREAU OF STANDARDS

By

W. S. Connor and W. H. Clatworthy

1. Introduction. This report describes the application of a new testing plan to 2.4 million barrels of cement produced by ten plants, compares the results with those from the current testing program, and suggests changes in the current sampling rate. The ten plants divide into two groups, one of nine plants from which grab samples were taken and the other of one plant from which car samples were taken. The report is mainly concerned with the group of nine plants.

This study has been made in accordance with the suggestion of the Technical Committee on Cement, Lime, and Plaster, which at its meeting on July 6, 1953 at the National Bureau of Standards discussed the plan as described in [1]* and requested further study of the plan to include all kinds of chemical and physical tests which are currently made on various types of cement.

The data studied in this report were supplied by the Concreting Materials section of the Mineral Products division of the National Bureau of Standards.** They were taken from the files of the testing laboratories in San Francisco, Seattle, Allentown, and Washington.

* Numbers in square brackets refer to references listed at the end of the text.

** The data studied were too extensive to be included in the report. However, the data and relevant calculations are on file in the Statistical Engineering Laboratory.

For each of the plants a long period of production for federal purchasing was studied, usually longer than a year. The data include all tests which were made during the period, with the order of testing preserved.

Only portland cement was investigated. The types included in the study were Type I, Type II (low alkali), and cement satisfying the specifications for both Types I and II.

A sample consists of about one quart of cement drawn from 500 barrels. Except for one plant from which railroad car samples were taken, all samples were grab samples, drawn from the flow of cement into the bins.

The plants investigated were about equally divided between the eastern and western regions of the country. The ~~lot~~ (bin) sizes varied greatly, from lots as small as 200 barrels to as large as 36,000 barrels. General information about the plants is given in Table 6.

The chemical tests made on the cement were determinations of the per cent silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), ferric oxide (Fe_2O_3), calcium oxide (CaO), magnesium oxide (MgO), sulfur trioxide (SO_3), total alkali (Alk), loss on ignition (Loss), insoluble residue (Res), tricalcium aluminate (3CA), and tricalcium silicate (3CS). The physical tests were determinations of the per

cent autoclave expansion (Auto), three-day compressive strength (3-day) and seven-day compressive strength (7-day) measured in pounds per square inch, air-entrainment (Air) measured in per cent volume, Blaine air permeability fineness (APF) measured in square centimeters per gram, initial (IS) and final (FS) setting time measured in hours and minutes, and false set (F Set) measured in millimeters. The specifications for these properties are given in [2].

It is convenient to distinguish between a test and a set of tests on a sample . A determination on one of the above properties will be called a test, and determinations on all the properties for a given type of cement will be called a set of tests.

For some of the properties tests were made on the "individual" samples of one quart from 500 barrels of cement. This is true of air permeability fineness and initial and final setting times. For the other properties tests were made on "composite" samples only, where a composite sample is a mixture of two, three, or four individual samples, usually four.

Although the philosophy of the testing plan considered in this report is the same as that in [1], some of the details have been changed. These modifications have the effect of simplifying the plan and of making it more sensitive to changes in the quality of production. The plan as modified for grab and car samples is described and illustrated by application to particular plants in section 3.

Section 4 contains a discussion of the results of applying the plan to grab samples from nine plants, section 5 contains miscellaneous suggestions and comments, and section 6 gives an evaluation of the plan.

The principal conclusions and recommendations drawn from the study are contained in the next section.

2. Conclusions and recommendations. The main conclusion of this report is that the present sampling and testing programs require unnecessarily large numbers of samples and tests. To rectify this situation it is suggested that

(1) The grab sampling rate be changed from one sample per 500 barrels to one sample per 2,000 barrels.

(2) The testing plan described herein for grab samples be adopted.

The suggested sampling rate would reduce the number of samples drawn to about one-fourth the present number. The proposed testing plan would reduce the number of tests performed to about 36 per cent of the present number.

Application of the proposed testing plan to a large sample of production showed that it is 92 per cent as effective in detecting violations of the specifications as the present plan.

3. The testing plan described and applied to a particular plant.

A. Grab samples. The plan used in this report for testing grab samples is a modification of the plan proposed in [1]. In order to make the modified plan clear it is applied in this section to plant A.

The outline of the plan for a property with a maximum specification is as follows. Past data are used to determine a number F, which is called the "frequent number" because it is used to decide whether "frequent" or "infrequent" testing is to be done. Frequent testing refers to testing as it now is being done (though a different definition is suggested in section 5) and infrequent testing refers to one test per lot (bin). The first sample for a lot is tested and the result of the test is compared with F. If the result is less than F, no more tests are run for the lot, but if the result is as large as F or larger than F the remaining samples from the lot are tested. The changes in this description required for a property with a minimum specification are apparent.

A very important aspect of the plan is that the decision about whether to do frequent or infrequent testing for a lot is made on the basis of a sample from that lot. It is evident that this procedure will cause some delay in deciding whether or not a lot is satisfactory. Accordingly, it might be thought preferable

to use the results from the preceding lot to decide whether or not to test the lot frequently. However, such a plan is inferior since it would not predict the quality of the lot with as much accuracy as the proposed plan.

The property which requires the longest testing time is 7-day strength. Presumably the other tests could be completed in 7 days or less. Hence a delay in evaluating a lot would occur only when 7-day strength required frequent testing. Such a delay would have occurred in 43 per cent of the lots studied from nine plants. This large percentage was due to relatively weak cement in 3 plants, for which a delay would have occurred for 67 per cent of the lots. For the remaining 6 plants a delay would have occurred for 16 per cent of the lots.

We now turn to the calculation of F for a particular property. For this purpose thirty-two test results from recent samples are used. If possible these should be the last thirty-two, arranged in chronological order. Beginning with the oldest, the test results are divided into four groups of eight each and the range _r_ (i.e., the difference between the largest and smallest) for each group is computed. These four ranges are added and their sum, Σr, is multiplied by 0.3, yielding a number $.3\Sigma r$ which for convenience we shall call _d_. If the property has a maximum specification, F

is obtained by subtracting d from the specification; if a minimum, by adding d to the specification.

Data from plant A will be used to illustrate the proposed plan. Tables 1 through 5 contain relevant information about plant A. Table 1 gives the lot sizes in barrels and the sampling dates. Tables 2 and 3 present the test results and Tables 4 and 5 show the detailed calculations needed for setting up the plan.

The details of the plan will be discussed for property Al_2O_3. The test results are given in Table 2, lot 1 being the oldest. Suppose that it had been decided to install the new plan immediately after lots 1 through 10 had been tested. At that time exactly 32 test results would have been available for calculating F. According to the procedure already described, these test results would have been grouped and the ranges computed in the following way:

	Group 1	Group 2	Group 3	Group 4
	6.0	5.8	5.9	6.0
	6.0	5.6	6.5	6.0
	6.1	5.8	6.3	5.8
	6.0	5.9	6.2	5.6
	6.3	5.7	6.2	5.5
	6.4	5.5	6.0	5.6
	6.3	5.6	6.1	5.3
	6.1	6.0	6.0	5.5
Range (r)	.4	.5	.6	.7

Further,

$$\Sigma r = .4+.5+.6+.7 = 2.2, \quad d = .3\Sigma r = .66 ,$$

and since the specification, 7.5, is a maximum,

$$F = 7.5 - .66 = 6.84,$$

and upon rounding, $F = 6.8$.

Beginning with lot 11 the new plan would have been put into effect. The first sample for the lot would have been tested and the result 5.4 compared with F = 6.8. Since 5.4 is less than 6.8 no further samples for lot 11 would have been tested. Proceeding in this way through successive lots, only one sample per lot would have been tested under the new plan, or a total of 18 samples for lots 11 through 28, instead of the 45 samples which actually were tested under the existing plan. Since no failures occurred for Al_2O_3 during the period, of course none would have been missed by the proposed plan.

It should be noted that the property 3CA is computed from Al_2O_3 and Fe_2O_3, instead of being directly determined [2]. Accordingly when the proposed plan requires frequent tests for 3CA, it is necessary to test both Al_2O_3 and Fe_2O_3 frequently, regardless of whether such tests are required by applying the plan to them individually. Except for those properties used in calculating the compounds 3CA and 3CS, frequent testing of one property for a particular lot does not require that frequent testing be done on all properties for that lot. For instance a particular lot may require 16 tests of air permeability fineness and only one for autoclave expansion.

Although in practice the plan would not be applied to the 32 sets of tests used to calculate F, in this study it was applied to all data, including the 32, since for some plants the amount of data was scanty. One could imagine that the plan had been set up from data obtained previous to that of this study and that the plan went into effect with the testing of lot 1.

The compound 3CA required frequent testing of lots 2,3,4, and 8, thus requiring more frequent testing of properties Al_2O_3 and Fe_2O_3 than would have been required by considering them alone. For plant A the proposed plan would have required 450 tests instead of the 1726 tests which actually were made. There were no violations of specifications in any of the data for plant A.

It is desirable that some provision be made for possible future changes in the variation among samples. Accordingly, after a suitable lapse of time, F could be recomputed from the most recent data. From the study of the data it does not appear that F need be recomputed frequently.

B. Car samples. For testing railroad car samples which now are taken at the rate of one per car a different plan is proposed. Since there is no logical grouping of cars into lots, the plan described for grab samples seems inappropriate, and instead it is suggested that a slight modification of the original plan of [1] be used.

For a property with a maximum specification a reasonable plan is as follows. From 32 recent test results Σr is computed exactly as described previously. Then Σr is multiplied by .2, instead of .3, to obtain a number $\underline{d}$. Next $\underline{d}$ is subtracted from the specification to determine F. Further, an infrequent number, I, is calculated by subtracting $\underline{d}$ from F.

The plan is put into effect by observing the test result from the first new car sample. If this result is as large as F, frequent testing is begun; if smaller than F, infrequent testing is begun. By frequent testing is meant testing one sample per car, as in current practice. By infrequent testing is mean testing a sample from every fifth car, say. When frequent testing is in progress it is continued until a test result as small as I is obtained, and then infrequent testing is done. Similarly, when infrequent testing is in progress it is continued until a result as large as F is obtained, and then frequent tests are made. The changes needed in this description for a property with a minimum specification are apparent.

This plan was applied to the only data available for car samples, the data for plant K. There were 64 cars each of approximately 400 barrels and one sample per car. The cement was type I. Unfortunately there were no violations of specifications

in the data, so that it was impossible to evaluate the plan. A proper evaluation of the plan would require that data containing 25 to 30 violations of the specifications be studied so that a good estimate of the percentage of violations detected by the new plan could be obtained.

The application of the plan to plant K revealed that the new plan would have required 196 tests instead of the 896 tests which actually were made.

4. Application of the proposed plan for grab samples to nine plants. This section presents results as to the effectiveness of the plan in eliminating tests while still detecting violations. The plan has been applied to grab samples from 2.4 million barrels of cement produced by nine different plants. The nine plants were chosen by the Concreting Materials section as typical of the population of plants under consideration. It is believed that the plants chosen constitute a representative sample, and since the sample is such a large one it should provide an excellent basis for evaluating the testing plan.

From the 2.4 million barrels 4,779 samples were taken and 29,888 chemical and physical tests were made on these samples. Of the 307 lots in the study there were 33 lots which contained one or more violations of the specification for at least one property.

General information about the plants is recorded in Table 6. Table 7 gives values of frequent numbers for all properties and all plants.

Using the present testing plan as the criterion, it was found that about 11 per cent of the lots violated the specification for at least one property. The number of lots which contained one or more violations is presented by plants and properties in Table 10. According to the table there were 37 such lots altogether, but these lots were not all distinct since there were two lots which violated the specification for more than one property. In fact, a lot from plant E violated the specifications for both SO_3 and 3CS and one from plant F for SO_3, Loss, APF, and 7-day strength. Hence there were 33 distinct lots with violations.

From the point of view of tests rather than lots, there were 59 test results which violated the specifications. Since there were 29,888 tests altogether, only about 2 tests in 1,000 revealed violations.

Of the 37 lot violations which were detected by the current testing plan, 34 would have been detected by the proposed plan. Thus, the proposed plan would have detected 92 per cent as many violations as the current plan. The detections by plants and properties are shown in parentheses in Table 10.

The proposed plan as described in section 3 would have reduced the number of tests from 29,888 to 10,722, thereby eliminating 64.0 per cent of the tests. For chemical tests alone the reduction would have been from 12,083 to 6,608 tests, a saving of 45.3 per cent; and for physical tests alone from 17,805 tests to 4,164 tests, a saving of 76.6 per cent. A detailed breakdown of testing frequencies by plants, properties, and testing plans is given in Table 8.

These savings can be somewhat further increased if suggestions made in section 5 are incorporated in the plan.

5. Miscellaneous suggestions and comments. In this section further modifications of the existing testing plan are proposed. These changes have the effect of reducing the number of samples taken, of further reducing the number of tests performed, and of making the tests more sensitive to the quality of the cement. These changes would fit easily into the proposed testing plan.

A. Individual samples. It is suggested that tests for all properties be made on individual samples instead of composite samples. This suggestion is based on the observation that individual samples are more sensitive to quality changes than are composite samples. Though this is intuitively reasonable, data supporting this observation are supplied in Tables 2 and

6 of [1]. Comparisons of the average ranges for composites and individuals in those tables show that the former tend to be smaller. Composite samples tend to conceal the variation within a lot and hence to defeat the purpose of the testing program.

If tests on individual samples were adopted for properties which now require composite samples, 32 sets of tests on individual samples would have to be run from which to calculate the F numbers prior to putting the plan into effect.

B. Relation between the size of a lot and the variation within the lot. There has been considerable interest in the effect of the size of a lot on the variation within a lot. To throw some light on this matter the data from plant H were studied. The data included lots of a wide variety of sizes, from 3,500 barrels to 36,000 barrels. Certain of these lots were selected, and for each property the standard deviation within the lot estimated. These estimates are shown in Table 11. Perusal of them indicates that the variation within a lot does not depend on the size of the lot.

From this study it appears that the number of tests needed to evaluate a lot is more or less independent of the size of the lot.

C. <u>Change of sampling rate</u>. It is apparent from the study of the nine plants that the variation within lots is small as compared with the variation between lots. This was illustrated in Table 4 of [1]. Hence it is wasteful to do extensive testing within a lot.

The uselessness of excessive testing is convincingly illustrated by a study of initial and final setting times, which usually were determined for individual samples. Of the 4,392 determinations made on each of initial and final setting times, not one violated the specification.

For most properties the current plan requires that four or fewer individual samples be composited and that the composite samples be tested. This means that one test is performed per 2,000 barrels of cement (except for the three properties requiring one test every 500 barrels). For lots of moderate size it is suggested that only one sample be drawn per 2,000 barrels and that this sample be tested as an individual according to the instructions given by the proposed plan. This procedure would not alter the rate of testing of those properties which presently require composite samples. However, for properties presently requiring individual samples, it would reduce the testing rate to almost one-fourth the present rate. Perhaps most important, it would cut the number of individual samples drawn to approximately one-fourth the current number.

In view of the discussion of paragraph B it seems inadvisable in the case of large lots to test one sample per 2,000 barrels. For a 36,000 barrel lot, for example, this would require 18 tests, many more than are needed for a sound evaluation of the lot. It therefore appears that consideration should be given to a sampling and testing scheme which takes lot size into account, providing proportionately fewer tests the larger the lot.

Such a plan might consist of drawing one sample every 2,000 barrels but testing according to the following schedule: (1) for lots containing not more than 10,000 barrels test one sample per 2,000 barrels, and (2) for larger lots test an additional sample for each additional 10,000 barrels. Thus, for example, for a 36,000 barrel lot 18 samples would be drawn from which 8 would be tested.

This schedule would be followed only when frequent tests are required. Infrequent testing would still require only one test per lot. It is to be noted that the suggested sampling rate is always one sample per 2,000 barrels, regardless of the testing rate.

D. Autoclave expansion. Also of interest is whether or not autoclave expansion can be tested under the proposed plan. Certain rare lots have been encountered in the experience of the Concreting Materials section in which autoclave expansion greatly

exceeds the specification for one or more samples from the lot, though not necessarily from all samples. The data in this study do not contain a single instance of such behavior. In fact there was only one lot which contained violations of the specification and these violations were small. The proposed plan would have detected them. In view of the fact that the proposed plan would eliminate 73 per cent of the tests on autoclave expansion and would detect most of the violations, it appears desirable to adopt the plan for this property also. It should be borne in mind that no plan can detect all rare, unpredictable, wild violations in segments of a lot.

E. Specifications on 3CA and 3CS. Another matter which should be considered is whether or not the specifications on 3CA and 3CS can be relaxed. Since they are computed from determinations on other chemicals [2], the testing plan for the other chemicals is dependent on their behavior. Thus, for example, if 3CS requires frequent testing for a lot, so does SiO_2 since it enters the computation of 3CS. For the nine plants the proposed testing plan would have required 267 tests on SiO_2 considered without regard to 3CS, but 711 tests because of frequent tests required on 3CS. Table 9 compares the numbers of tests required by SiO_2, Al_2O_3, Fe_2O_3, and SO_3 when the proposed testing plan is applied to them individually with the numbers required when 3CA and 3CS are taken into account.

F. <u>Summary of miscellaneous suggestions</u>. In summary it is recommended that in setting up the proposed testing plan consideration be given to the following suggestions:

1) The rate of drawing samples be changed from one sample per 500 barrels to one sample per 2,000 barrels.

2) Testing of composite samples be discarded and testing done on individual samples only.

3) A frequent testing scheme which gives consideration to the size of the lot be adopted, the scheme to provide for proportionally fewer samples the larger the lot.

4) An investigation of the possibility of relaxation of the specifications for properties 3CA and 3CS be made. Such relaxation might result in a substantial reduction in the frequency of testing related properties.

5) Autoclave expansion be tested in the same manner as the other properties.

6. <u>Evaluation of the proposed plan for grab samples</u>. In this section the proposed plan for grab samples is examined with regard to the protection which it provides, the potential savings, and the possible new costs.

As was seen in section 4, the proposed testing plan is 92 per cent as effective in detecting violations as the present plan. This, coupled with the impression that the present plan is a very stringent one, indicates that the proposed plan would furnish very good protection.

Because exact cost figures are not available to the writers, no attempt has been made to evaluate the annual savings which would be realized by adoption of the plan. However it is believed that adoption of the suggestion that one-fourth as many samples be drawn would greatly reduce the cost of sampling. Also it has been seen that the proposed testing plan would eliminate at least 64 per cent of the current tests, thereby considerably reducing the testing expense.

Added costs of the new plan are small. To set up the plan calculations must be made from past data. It is estimated that one worker could take the necessary observations from the files and made the calculations for one plant in four hours.

Adoption of the proposed sampling and testing plans would result in sizeable savings with no serious decrease in protection.

7. Acknowledgment. The authors wish to acknowledge the generous and invaluable assistance of D. N. Evans of the Concreting Materials section. He furnished the data on which the report is based as well as very helpful advice about the technical aspects of the current sampling and testing program.

REFERENCES

[1] Clatworthy, W. H., Connor, W. S., and Evans, D. N., "A testing plan for cement", National Bureau of Standards Report 2560, June, 1953.

[2] "Federal specification, cements, portland", SS-C-192a, U. S. Government Printing Office, April 22, 1952.

Table 1

BIN SIZES AND SAMPLE DATES,
PLANT A

Lot No.	Bin No.	Lot Size (barrels)	Sample Date
1	6-5	4,000	1/28-29/52
2	7-4	3,000	2/21-22/52
3	6-6	4,000	3/31/4/1/52
4	9-10	4,000	4/14-15/52
5	11-15	4,000	4/28-29/52
6	22-6	9,000	5/12-14/52
7	9-11	4,000	5/14-15/52
8	22-7	8,500	6/16-18/52
9	21-5	9,000	6/30-7/1/52
10	22-8	8,500	7/21-23/52
11	21-6	8,500	8/11-12/52
12	22-9	8,000	8/18-20/52
13	21-7	8,000	9/15-16/52
14	22-10	8,000	10/6-7/52
15	8-9	4,000	10/20-21/52
16	10-7	4,000	10/27-28/52
17	7-5	4,000	11/19-20/52
18	6-7	4,000	12/3-4/52
19	10-8	4,000	1/26/53
20	7-6	4,000	3/9-10/53
21	10-9	4,000	4/2/53
22	4-4	4,000	4/6/53
23	10-10	4,000	5/1-2/53
24	4-5	4,000	5/25-26/53
25	6-8	4,000	6/15-16/53
26	7-7	4,000	7/7-8/53
27	8-10	4,000	7/27-28/53
28	6-9	4,000	8/31/53

Table 2

TEST RESULTS, COMPOSITE SAMPLES, PLANT A

Lot No.	Al_2O_3	Fe_2O_3	MgO	SO_3	Loss	Res.	3CA	Auto	Strength 3-Day	Strength 7-Day	Air
1	6.0	2.2	3.2	1.9	0.8	0.2	12	0.23	1470	2680	6.8
	6.0	2.2	3.2	1.6	0.7	0.2	12	0.22	1440	2690	7.5
2	6.1	2.1	3.1	1.6	0.8	0.3	13	0.19	1570	2920	7.1
	6.0	2.2	3.0	1.8	0.8	0.3	12	0.19	1540	2740	7.5
3	6.3	2.2	3.0	1.9	0.7	0.2	13	0.24	1620	2810	5.9
	6.4	2.2	2.9	2.0	0.7	0.2	13	0.22	1620	2730	5.9
4	6.3	2.3	2.7	1.7	1.3	0.3	13	0.21	1730	2930	3.8
	6.1	2.3	2.7	1.8	1.1	0.2	12	0.17	1680	2750	2.7
5	5.8	2.0	3.3	2.2	0.8	0.3	12	0.27	1480	2470	6.7
	5.6	2.0	3.3	2.5	1.1	0.3	11	0.29	1590	2680	6.3
6	5.8	2.1	3.6	1.8	1.0	0.2	12	0.20	1770	2940	3.3
	5.9	2.3	3.6	2.0	0.9	0.2	12	0.20	1860	3110	5.3
	5.7	2.2	3.6	1.9	0.8	0.1	11	0.19	1780	2850	4.4
	5.5	2.2	3.7	1.7	0.7	0.2	11	0.18	1700	2730	4.6
	5.6	2.1	3.6	1.9	0.7	0.2	11	0.18	1740	2880	4.0
7	6.0	2.1	3.5	1.9	1.0	0.4	12	0.22	1820	2980	6.2
	5.9	2.1	3.6	2.2	1.1	0.5	12	0.23	1990	3180	6.2
8	6.5	2.2	3.2	1.7	0.9	0.2	13	0.23	1820	3050	5.4
	6.3	2.2	3.2	1.6	1.0	0.1	13	0.22	1560	2730	4.2
	6.2	2.2	3.3	1.7	0.9	0.1	13	0.22	1670	2840	4.4
	6.2	2.2	3.3	1.6	0.9	0.1	13	0.23	1570	2680	4.4
	6.0	2.1	3.3	1.7	1.0	0.2	12	0.24	1650	2870	4.7
9	6.1	2.2	3.2	1.7	0.9	0.3	12	0.21	1780	3010	4.2
	6.0	2.2	3.2	1.8	0.9	0.2	12	0.19	1940	3030	3.9
	6.0	2.2	3.3	1.8	0.8	0.2	12	0.20	1850	3110	3.7
	6.0	2.2	3.4	1.9	1.0	0.2	12	0.21	1820	2950	3.9
	5.8	2.1	3.2	1.8	1.0	0.2	12	0.23	1990	3100	3.3

Table 2 (Continued)

Lot No.	Al_2O_3	Fe_2O_3	MgO	SO_3	Loss	Res.	3CA	Auto	Strength 3-Day	Strength 7-Day	Air
10	5.6	2.4	3.1	1.7	1.0	0.2	11	0.15	1700	2930	2.9
	5.5	2.4	3.0	2.0	1.0	0.2	11	0.17	1710	2720	2.9
	5.6	2.4	2.7	2.0	1.0	0.3	11	0.17	1790	3010	3.2
	5.3	2.3	2.7	2.1	0.8	0.3	10	0.18	1820	2920	3.2
	5.5	2.3	3.0	1.8	0.8	0.3	11	0.17	1640	2850	3.2
11	5.4	2.4	3.6	1.9	0.9	0.2	10	0.15	1500	2600	3.6
	5.2	2.3	3.6	1.9	1.1	0.2	10	0.14	1590	2580	2.7
	5.2	2.3	3.5	1.9	0.9	0.2	10	0.15	1420	2380	3.2
	5.6	2.3	3.2	1.9	0.9	0.2	11	0.15	1440	2430	3.1
	5.4	2.3	3.3	1.8	0.8	0.2	10	0.14	1340	2420	3.4
12	5.6	2.3	3.1	1.9	1.1	0.4	11	0.13	1350	2210	2.8
	5.6	2.5	3.2	1.9	1.3	0.3	11	0.12	1380	2260	2.4
	5.4	2.6	3.2	1.7	0.9	0.3	10	0.11	1330	2260	2.7
	5.5	2.5	3.2	2.0	1.0	0.3	10	0.12	1360	2180	2.7
13	5.8	2.4	3.3	1.9	1.0	0.1	11	0.12	1390	2270	6.0
	5.7	2.3	3.4	2.1	1.4	0.1	11	0.14	1580	2470	6.1
	5.5	2.3	3.3	1.9	1.0	0.1	11	0.13	1580	2630	6.1
	5.5	2.3	3.4	2.0	1.1	0.1	11	0.13	1540	2470	6.4
14	5.2	2.2	3.2	1.8	1.1	0.3	10	0.15	1480	2440	4.4
	5.6	2.1	3.4	1.9	1.0	0.3	11	0.14	1470	2540	4.4
	5.1	2.1	3.3	2.0	1.0	0.2	10	0.14	1440	2530	3.7
	5.2	2.1	3.3	2.3	1.1	0.3	10	0.13	1340	2320	6.5
15	5.1	2.1	3.7	2.0	1.0	0.2	10	0.17	1580	2410	6.7
	4.8	2.2	3.8	2.0	1.1	0.2	9	0.15	1520	2460	2.6
16	5.0	2.1	3.7	1.8	0.8	0.2	10	0.17	1350	2375	4.4
	5.0	2.1	3.7	1.8	1.0	0.2	10	0.16	1420	2360	4.0

Table 2 (Continued)

Lot No.	Al_2O_3	Fe_2O_3	MgO	SO_3	Loss	Res.	3CA	Auto	Strength 3-Day	Strength 7-Day	Air
17	4.8	1.9	3.9	1.9	1.1	0.2	10	0.18	1500	2460	4.1
	4.7	1.9	3.8	1.9	1.0	0.2	9	0.20	1360	2260	4.8
18	4.8	2.1	0.9	1.8	0.9	0.3	3	0.15	1340	2380	4.6
	5.0	2.1	0.9	1.8	0.9	0.3	10	0.15	1320	2260	4.2
19	5.3	2.4	3.6	1.8	0.6	0.1	10	0.13	1310	2290	5.8
	5.2	2.4	3.7	1.8	0.6	0.1	10	0.14	1290	2180	6.0
20	5.0	2.2	3.6	1.6	0.6	0.2	9	0.15	1420	2480	6.1
	4.9	2.2	3.5	1.6	0.6	0.1	9	0.15	1500	2570	6.2
21	5.3	2.3	2.6	1.7	1.1	0.2	10	0.14	1550	2680	4.9
	5.5	2.3	2.6	2.0	1.2	0.2	11	0.14	1660	2750	4.2
22	5.4	2.2	3.6	1.6	1.2	0.2	11	0.15	1370	2330	4.4
	5.3	2.2	3.6	1.7	0.9	0.1	10	0.15	1310	2090	4.2
23	4.7	1.9	3.6	1.6	1.0	0.2	9	0.18	1190	2130	5.6
	4.5	1.8	3.4	2.0	0.8	0.2	9	0.17	1200	2220	6.2
24	5.3	2.0	3.2	1.5	1.2	0.4	11	0.17	1520	2520	4.7
	5.6	2.0	3.5	1.5	1.0	0.5	11	0.17	1500	2570	5.7
25	5.1	2.2	3.2	1.6	0.8	0.2	10	0.12	1730	2610	6.5
	5.1	2.2	3.2	1.8	1.0	0.2	10	0.12	1660	2710	6.5
26	4.8	2.1	3.7	1.7	0.9	0.1	9	0.12	2120	2650	5.9
	4.9	2.1	3.7	1.8	0.8	0.2	9	0.12	2080	2540	5.8
27	4.9	1.9	3.4	1.6	1.1	0.2	10	0.16	1660	2810	5.5
	4.7	1.9	3.5	1.7	1.0	0.3	9	0.16	1720	2800	4.6
28	5.0	2.1	3.6	1.5	0.9	0.2	10	0.14	1550	2580	5.1
	5.1	2.1	3.7	1.6	1.0	0.2	10	0.13	1670	2750	5.6

Table 3

TEST RESULTS, INDIVIDUAL SAMPLES,
PLANT A

Lot No.	APF	IS	FS
1	3070	3:20	6:30
	3070	3:15	6:25
	3200	3:15	6:25
	3280	3:40	6:50
	3230	3:35	6:45
	3230	3:30	6:40
	3260	3:30	6:40
	3230	3:30	6:40
2	3380	3:10	6:20
	3400	3:05	6:20
	3310	3:05	6:15
	3280	3:00	6:15
	3430	3:25	6:30
	3450	3:25	6:30
3	3350	3:35	6:40
	3380	3:35	6:40
	3400	3:30	6:35
	3330	3:30	6:35
	3500	3:25	6:30
	3430	3:25	6:30
	3330	3:25	6:30
	3430	3:25	6:30
4	3640	3:30	6:25
	3640	3:20	6:25
	3570	3:15	6:20
	3520	3:15	6:20
	3640	3:10	6:15
	3540	3:10	6:15
	3590	3:10	6:15
	3590	3:10	6:15
5	3280	2:55	5:35
	3310	3:10	6:00
	3380	3:05	6:00
	3350	2:45	5:25
	3400	2:45	5:25
	3350	2:45	5:25
	3450	2:45	5:25
	3400	2:55	5:50
6	3400	4:05	6:50
	3450	4:00	6:45
	3380	4:00	6:45
	3400	3:55	6:40
	3480	3:55	6:40
	3590	3:50	6:35
	3400	3:45	6:30
	3380	3:45	6:30
	3450	3:45	6:30
	3350	3:50	6:35
	3280	3:45	6:30
	3230	3:40	6:25
	3350	3:45	6:30
	3350	3:40	6:25
	3430	3:50	6:35
	3280	3:40	6:25
	3280	3:35	6:20
	3280	3:40	6:25
7	3280	3:05	5:55
	3430	3:00	5:55
	3430	3:00	5:50
	3520	2:55	5:45
	3480	2:50	5:45
	3540	2:50	5:40
	3680	2:50	5:40
	3480	2:45	5:40
8	3500	3:10	6:00
	3750	3:05	5:55
	3330	3:05	5:55
	3450	3:00	5:50
	3400	3:00	5:50
	3400	2:55	5:45
	3350	2:55	5:45
	3330	2:50	5:40
	3380	2:50	5:40
	3310	2:55	5:45
	3520	2:50	5:40
	3330	2:50	5:40
	3330	2:50	5:40
	3380	2:45	5:35
	3310	2:55	5:45
	3390	2:45	5:35
	3350	2:45	5:35

* See end of Table.

Table 3 (Continued)

Lot No.	APF	IS	FS
9	3400	3:50	6:10
	3330	3:50	6:05
	3400	3:45	6:05
	3480	3:45	6:00
	3430	3:40	6:00
	3380	3:40	5:50
	3450	3:35	5:50
	3380	3:35	5:50
	3350	3:35	5:45
	3500	3:40	6:00
	3480	3:35	5:45
	3430	3:30	5:45
	3380	3:30	5:45
	3400	3:30	5:40
	3260	3:40	5:55
	3520	3:30	5:40
	3450	3:30	5:40
	3400	3:25	5:35
10	3280	4:20	7:35
	3200	4:20	7:30
	3280	4:15	7:25
	3330	4:10	7:25
	3400	4:10	7:20
	3280	4:00	7:15
	3280	4:00	7:15
	3380	4:00	7:10
	3350	4:00	7:10
	3350	4:05	7:15
	3330	3:55	7:10
	3310	3:55	7:10
	3310	3:55	7:05
	3540	3:55	7:05
	3380	4:05	7:15
	3400	3:50	7:05
	3310	3:50	7:00
11	3180	4:00	7:05
	3260	3:55	7:05
	3330	3:55	7:00
	3330	3:50	7:00
	3330	3:50	6:55
	3330	3:40	6:50
	3280	3:40	6:45
	3200	3:40	6:45
	3260	3:35	6:45
	3260	3:45	6:55
	3310	3:35	6:40
	3280	3:35	6:40
	3310	3:30	6:40
	3350	3:30	6:35
	3310	3:45	6:50
	3200	3:30	6:35
	3200	3:30	6:35
12	3130	4:05	7:00
	3200	4:00	6:55
	3310	3:55	6:55
	3180	3:55	6:50
	3310	3:50	6:45
	3260	3:45	6:40
	3200	3:40	6:35
	3130	3:40	6:35
	2910	3:45	6:45
	3200	3:35	6:35
	3260	3:35	6:35
	3180	3:35	6:30
	3200	3:35	6:30
	3200	3:45	6:40
	3260	3:30	6:30
	3180	3:40	6:35

Table 3 (Continued)

Lot No.	APF	IS	FS	Lot No.	APF	IS	FS
13	3300	4:00	5:55	16	3360	3:50	5:55
	3280	4:00	5:55		3360	3:45	5:50
	3380	3:45	5:35		3440	3:40	5:50
	3250	3:45	5:35		3300	3:35	5:40
	3440	3:25	5:35		3330	3:30	5:40
	3440	3:40	5:25		3410	3:30	5:35
	3330	3:30	5:35		3300	3:30	5:35
	3380	3:30	5:30		3300	3:25	5:35
	3410	3:10	5:20	17	3280	4:05	5:45
	3330	3:20	5:35		3280	4:00	5:40
	3440	3:10	5:20		3250	4:00	5:40
	3440	3:25	5:25		3300	3:55	5:35
	3440	3:10	5:25		3170	3:50	5:30
	3440	3:35	5:15		3220	3:50	5:25
	3380	3:40	5:30		3220	3:45	5:25
	3440	3:20	5:15		3220	3:40	5:20
14	3360	3:25	6:10	18	3230	3:50	6:10
	3380	3:25	6:10		3280	3:45	6:05
	3380	3:20	6:05		3280	3:45	6:05
	3380	3:20	6:05		3170	3:40	6:00
	3460	3:15	6:00		3170	3:35	5:55
	3520	3:10	5:55		3400	3:30	5:50
	3380	3:05	5:55		3250	3:30	5:50
	3540	3:05	5:50		3200	3:25	5:45
	3440	3:05	5:50	19	3260	3:50	6:10
	3460	3:10	6:00		3180	3:50	6:10
	3460	3:05	5:50		3150	3:45	6:05
	3380	3:00	5:45		3040	3:45	6:05
	3360	3:00	5:45		3040	3:45	6:05
	3540	3:00	5:45		3300	3:40	6:00
	3520	3:10	5:55		3370	3:40	6:00
	3460	3:00	5:45		3260	3:40	6:00
15	3280	3:25	5:55	20	3070	3:25	6:30
	3520	3:25	5:55		3220	3:25	6:25
	3380	3:20	5:50		3250	3:20	6:25
	3280	3:15	5:50		3160	3:15	6:20
	3380	3:15	5:45		3440	3:15	6:20
	3410	3:15	5:45		3330	3:15	6:20
	3300	3:10	5:40		3130	3:15	6:20
	3300	3:10	5:40		3160	3:15	6:20

Table 3 (Continued)

Lot No.	APF	IS	FS	Lot No.	APF	IS	FS
21	3550	2:50	5:20	26	3160	3:40	6:15
	3410	2:50	5:20		3110	3:35	6:15
	3480	2:45	5:15		3340	3:35	5:55
	3480	2:45	5:15		3290	3:30	5:50
	3350	2:45	5:15		3210	3:30	6:05
	3560	2:45	5:15		3160	3:30	6:05
	3560	2:40	5:10		3160	3:30	6:05
	3380	2:40	5:10		3340	3:25	6:00
22	3270	3:25	6:10	27	3260	3:10	6:05
	3300	3:20	6:05		3390	3:05	6:05
	3300	3:20	6:05		3290	3:05	6:00
	3430	3:20	6:05		3390	3:00	5:55
	3430	3:15	6:00		3340	3:00	5:55
	3350	3:15	6:00		3340	2:55	5:50
	3250	3:15	6:00		3340	2:55	5:50
	3250	3:15	6:00		3340	2:50	5:45
23	3060	3:15	6:05	28	3160	3:20	5:50
	3060	3:10	6:00		3190	3:20	5:45
	3030	3:10	6:00		3260	3:15	5:45
	3120	3:05	5:55		3130	3:10	5:40
	3060	3:05	5:55		3260	3:10	5:40
	3150	3:00	5:50		3260	3:10	5:40
	3150	3:00	5:50		3190	3:10	5:35
	3150	3:00	5:50		3240	3:05	5:35
24	3310	4:00	6:50				
	3290	4:00	6:50				
	3210	3:55	6:45				
	3210	3:55	6:45				
	3190	3:55	6:45				
	3260	3:50	6:40				
	3260	3:50	6:40				
	3190	3:50	6:40				
25	3290	3:50	6:15				
	3260	3:50	6:10				
	3260	3:45	6:10				
	3290	3:45	6:05				
	3340	3:40	6:05				
	3340	3:40	6:00				
	3310	3:35	6:00				
	3340	3:35	5:55				

Air permability fineness (APF) is measured in cm^2/g and initial set (IS) and final set (FS) are in hours and minutes.

Table 4

CALCULATION OF F FOR COMPOSITES, PLANT A

	Al_2O_3 %	Fe_2O_3 %	MgO %	SO_3 %	Loss %	Res %	3CA %	Auto %	Strength 3-day lb/in^2	Strength 7-day lb/in^2	Air %
r_1	.4	.2	.5	.4	.6	.1	1	.07	290	250	4.8
r_2	.5	.3	.4	.8	.4	.3	1	.11	380	640	3.4
r_3	.6	.1	.4	.6	.2	.4	1	.05	430	500	2.3
r_4	.7	.3	.7	.4	.2	.1	2	.08	350	390	1.0
Σr_i	2.2	0.9	2.0	2.2	1.4	.9	5	.31	1450	1780	11.5
$0.3\Sigma r_i$	0.7	0.3	0.6	0.7	0.4	.27	1.5	.09	435	534	3.45
Max. Spec.	7.5	6.0	5.0	2.5	3.0	.75	15	.50	----	----	12
Min. Spec.	---	---	---	---	---	---	---	---	900	1800	---
F	6.8	5.7	4.4	1.8	2.6	0.5	13	.41	1330	2330	8.6

$$\hat{\sigma} = \bar{R}/d_4 = \Sigma r_i/4(2.059)$$

$$2.47\hat{\sigma} = 0.3\Sigma r_i$$

Table 5

CALCULATION OF F FOR INDIVIDUALS, PLANT A

	APF (cm^2/g)	IS (minutes)	FS (minutes)
r_1	210	25	25
r_2	170	35	25
r_3	310	10	10
r_4	360	20	45
Σr_i	1050	90	105
$0.3\ \Sigma r_i$	315	27	32
Max. Spec.	----	---	600
Min. Spec.	2600	60	---
F	2920	87	568

Table 6

GENERAL INFORMATION ABOUT PLANTS

Plant	Type of Cement	Period Sampled	No. of Barrels	No. of Lots	No. of Samples	No. of Tests
A	I	1/28/52-8/31/53	146,500	28	293	1,726
B	I	2/26/52-7/10/53	101,200	15	200	1,227
C	I	7/29/52-8/13/53	64,500	13	129	744
D	I&II	4/5/53-8/28/53	300,000	28	600	3,302
E	I&II	11/8/51-8/24/53	303,000	29	606	3,508
F	I&II	4/11/52-3/5/53	249,500	53	499	3,616
G	I&II	7/23/52-8/29/53	302,163	28	605	3,656
H	II low alkali	8/12/52-10/6/53	578,000	40	1,156	7,358
J	II low alkali	3/26/52-9/13/53	342,100	73	691	4,751
		Totals	2,386,963	307	4,779	29,888

Table 7

VALUES OF FREQUENT NUMBER (F)

Tests \ Plants	A	B	C	D	E	F	G	H	J
A. Chemical Tests									
S_iO_2	----	----	----	21.7	21.5	21.5	21.4	22.0	22.0
Al_2O_3	6.8	7.0	7.0	5.4	5.6	5.5	5.6	5.3	5.7
Fe_2O_3	5.7	5.8	5.8	5.7	5.7	5.8	5.8	5.7	5.7
MgO	4.4	4.4	4.5	4.8	4.7	4.5	4.5	4.6	4.5
SO_3	1.8	2.1	2.0	1.6	1.4	1.5	1.8	1.5	1.5
Alk	----	----	----	----	.49	----	----	.51	.52
Loss	2.6	2.6	2.5	2.8	2.7	2.2	2.5	2.1	2.6
Res	0.5	0.6	0.5	0.6	0.6	0.5	0.7	0.6	0.7
3 CA	13	14	14	7	6	6	7	6	7
3 CS	----	----	----	46	45	46	45	41	43
B. Physical Tests									
APF	2920	3040	3120	3350	3230	3830	3170	3390	3440
Auto	.41	.26	.37	.45	.44	.43	.43	.47	.43
IS	87	81	117	87	93	76	78	87	111
FS	568	567	541	573	568	564	582	542	564
3-day	1330	1450	1480	1490	1080	1470	1195	1400	1250
7-day	2330	2700	2540	2630	2160	2370	2315	2500	2190
Air	8.6	10.0	9.4	10.1	8.2	10.2	11.0	10.4	10.1
F Set	----	----	----	----	46	----	31	----	32

Table 8

COMPARISON OF NUMBER OF TESTS UNDER THE PRESENT AND PROPOSED PLANS

Tests \ Plants	A	B	C	D	E	F	G	H	J	Totals
A. Chemical Tests										
S_iO_2 (old)	---	---	---	152	153	163	153	296	217	1134
(new)	---	---	---	33	109	102	85	224	158	711
										37.3%
Al_2O_3 (old)	77	57	39	152	153	163	153	296	217	1307
(new)	35	21	27	142	109	155	126	271	158	1044
										20.1%
Fe_2O_3 (old)	77	57	39	152	153	163	153	296	217	1307
	35	15	27	142	109	155	126	271	158	1038
										20.6%
MgO (old)	77	57	39	152	153	163	153	296	217	1307
(new)	28	15	13	28	29	53	61	40	73	340
										74.0%
SO_3 (old)	77	57	39	152	153	163	153	296	217	1307
(new)	54	57	35	80	147	154	103	293	202	1125
										13.9%
Alk (old)	---	---	---	---	153	---	---	296	217	666
(new)	---	---	---	---	29	---	---	78	86	193
										71.0%
Loss (old)	77	57	39	152	153	163	153	296	217	1307
(new)	28	15	13	28	29	57	28	49	73	320
										75.5%
Res (old)	77	57	39	152	153	163	153	296	217	1307
(new)	28	15	15	28	29	63	28	49	73	328
										74.9%

Table 8 (Continued)

Tests \ Plants	A	B	C	D	E	F	G	H	J	Totals
3CA (old)	77	57	39	152	153	163	153	296	217	1307
(new)	35	15	27	142	29	155	102	220	73	798
										38.9%
3CS (old)	---	---	---	152	153	163	153	296	217	1134
(new)	---	---	---	33	109	102	85	224	158	711
										37.3%
Totals (old)	539	399	273	1368	1530	1467	1377	2960	2170	12,083
(new)	243	153	157	656	728	996	744	1719	1212	6,608
% Tests Elim.	54.9	61.7	42.5	52.0	52.4	32.1	46.0	41.9	44.1	45.3%
B. Physical Tests										
Auto (old)	77	57	39	152	153	163	153	296	217	1307
(new)	28	53	17	28	29	53	34	40	73	355
										72.8%
3-day (old)	77	57	39	152	153	163	153	296	217	1307
Str. (new)	30	15	15	55	29	82	28	141	91	486
										62.8%
7-day (old)	77	57	39	152	153	163	153	296	217	1307
Str. (new)	37	21	15	35	37	136	60	247	136	724
										44.6%
Air (old)	77	57	39	152	153	163	153	296	217	1307
(new)	28	15	13	29	39	53	28	40	73	318
										75.7%
APF (old)	293	200	129	126	162	499	309	1132	494	3344
(new)	28	106	49	75	7	411	15	244	287	1222
										63.4%

Table 8 (Continued)

Plants / Tests	A	B	C	D	E	F	G	H	J	Totals
IS (old)	293	200	93	600	559	499	605	1041	502	4392
(new)	28	15	13	28	29	53	28	40	73	307
										93.0%
FS (old)	293	200	93	600	559	499	605	1041	502	4392
(new)	28	15	13	28	29	53	28	63	73	330
										92.5%
F Set (old)	---	---	---	---	86	---	148	---	215	449
(new)	---	---	---	---	86	---	144	---	192	422
										6.0%
Totals (old)	1187	828	471	1934	1978	2149	2279	4398	2581	17,805
(new)	207	240	135	278	285	841	365	815	998	4,164
% Tests Elim.	82.6	71.0	71.3	85.6	85.6	60.9	84.0	81.5	61.3	76.6%
Grand (old)	1,726	1,227	744	3,302	3,508	3,616	3,656	7,358	4,751	29,888
Totals (new)	450	393	292	934	1,013	1,837	1,109	2,534	2,210	10,772
% Tests Elim.	73.9	68.0	60.8	71.7	71.1	49.2	69.7	65.6	53.5	64.0%

Table 9

EFFECT OF SPECIFICATIONS FOR 3CA AND 3CS ON THE FREQUENCY OF TESTING OF SiO_2, Al_2O_3, Fe_2O_3, AND SO_3

Plants \ Tests		SiO_2	Al_2O_3	Fe_2O_3	SO_3
A(1)		----	35	35	54
(2)		----	28	28	54
B(1)		----	21	15	57
(2)		----	21	15	57
C(1)		----	27	27	35
(2)		----	17	13	35
D(1)		33	142	142	80
(2)		28	28	28	75
E(1)		109	109	109	147
(2)		29	29	29	135
F(1)		102	155	155	154
(2)		53	53	53	148
G(1)		85	126	126	103
(2)		34	28	28	58
H(1)		224	271	271	293
(2)		50	49	40	224
J(1)		158	158	158	202
(2)		73	73	73	184
Total No. Tests	(old)	1134	1307	1307	1307
" " "	(1)	711	1044	1038	1125
" " "	(2)	267	326	307	970
% Tests Elim.	(1)	37.3	20.1	20.6	13.9
% " "	(2)	76.5	75.1	76.5	25.8

Note - Numbers opposite (1) give testing frequencies under proposed plan with present specifications on 3CA and 3CS, while numbers opposite (2) give testing frequencies under proposed plan when specifications on 3CA and 3Cs are ignored.

Table 10

NUMBER OF LOTS FOR WHICH ONE OR MORE TESTS VIOLATED THE SPECIFICATIONS AND NUMBER DETECTED BY THE PROPOSED PLAN
(Numbers in parentheses denote bad lots detected.)

Tests \ Plants	A	B	C	D	E	F	G	H	J	Totals
A. Chemical Tests										
S_iO_2	--	--	---	0	0	0	1(0)	0	0	1(0)
Al_2O_3	0	0	0	0	0	0	0	0	0	0
Fe_2O_3	0	0	0	0	0	0	0	0	0	0
MgO	0	0	0	0	0	0	0	0	0	0
SO_3	0	0	0	1(1)	7(7)	4(4)	1(1)	0	1(1)	14(14)
Alk	--	--	---	---	0	---	---	0	0	0
Loss	0	0	0	0	0	1(1)	0	0	0	1(1)
Res	0	0	0	0	0	0	0	0	0	0
3 CA	0	0	0	0	0	0	0	0	0	0
3 CS	--	--	---	0	1(1)	1(1)	0	2(2)	1(1)	5(5)
B. Physical Tests										
Auto	0	0	0	0	0	0	1(1)	0	0	1(1)
3-day	0	0	0	0	0	0	0	0	0	0
7-day	0	0	0	0	3(2)	1(1)	0	0	0	4(3)
Air	0	0	0	1(1)	0	0	0	0	0	1(1)
APF	0	0	1(1)	0	0	1(0)	0	0	0	2(1)
IS	0	0	0	0	0	0	0	0	0	0
FS	0	0	0	0	0	0	0	0	0	0
F Set	--	--	---	---	3(3)	---	1(1)	---	4(4)	8(8)
Totals	0	0	1(1)	2(2)	14(13)	8(7)	4(3)	2(2)	6(6)	37(34)

Table 11

ESTIMATES OF WITHIN LOTS STANDARD DEVIATION, PLANT H

No. of tests per lot*	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Alk	Loss	Res
2	.40	.089	.18	---	.089	.22	.018	.22	.044
3	.089	.12	.030	.059	.030	.059	.021	.059	.089
6	.22	.13	.11	.25	.066	.12	.028	.17	.039
9	.33	.15	.11	.26	.090	.18	.021	.13	.023
17,18	.25	.12	.083	.22	.055	.17	.033	.11	.028

Table 11 (Continued)

No. of tests per lot*	3CA	3CS	Auto	3-day	7-day	Air
2	.44	2.66	.0044	212.8	288.1	.80
3	.30	1.18	.0030	103.4	227.4	.44
6	.39	2.89	.0067	152.6	182.8	.59
9	.56	2.58	.010	220.0	231.2	.74
17,18	.41	2.21	.032	164.4	207.2	.87

* The number of barrels of cement per lot can be estimated by multiplying the number of tests per lot by 2,000.

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